[10537/311]

METHOD FOR CUTTING FREEFORM SURFACES, CUTTING TOOL AND USE OF THE CUTTING TOOL

FIELD OF THE INVENTION
The present invention relates to a method for cutting freeform surfaces, to a cutting tool and to the use of the cutting tool.

5

The present invention relates to the area of cutting technology, e.g., to HSC cutting (high-speed cutting), which is also referred to as HPC cutting (high performance cutting).

10   ### BACKGROUND INFORMATION
Conventionally, so-called spherical cutters are used for cutting freeform surfaces. Such spherical cutters have a tool shank and a tool head attached to the tool shank, a radius of the tool head corresponding to a radius of the tool shank in
15   the spherical cutter. The tool head therefore does not protrude laterally beyond an outer lateral surface of the tool shank.

For minimizing undesired residual lines formed during cutting,
20   the use of a spherical cutter entails restrictions with respect to the line spacing to be maintained between the cutting paths of the cutting tool. This results in a relatively high number of required cutting paths, which determines the time required for cutting. From the point of
25   view of high-speed cutting or high-performance cutting, however, short cutting times may be desirable.

SUMMARY
According to an example embodiment of the present invention, a
30   workpiece is cut by a cutting tool such that a desired freeform surface may be obtained. For cutting purposes, the

SUBSTITUTE SPECIFICATION

EV 320 245 601 US

cutting tool is moved along at least one defined cutting path relative to the workpiece. A cutting tool (a so-called special cutter) is used, the tool head of which has a greater radius than a tool shank of the cutting tool, without,

5 however, the tool head protruding laterally beyond an outer lateral surface of the tool shank. This may provide that cutting results in low residual line formation. Accordingly, it may be possible to increase the line spacing during cutting and reduce the time required for cutting.

10

First cutting paths may be produced by using a spherical cutter, its radius of the tool head corresponding to the radius of the tool shank. From these first cutting paths, second cutting paths are produced for the cutting tool to be

15 used, the tool head of which has a greater radius than a tool shank of the same. This may allow for a particularly simple and quick production of the cutting paths for the cutting tool to be used. This may be used when the CAM system used does not support special cutters.

20

Example embodiments of the present invention are explained in more detail below with reference to the appended Figures.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Figure 1 illustrates a conventional cutting tool in a side view.

Figure 2 is a side view of a cutting tool according to an example embodiment of the present invention.

30

DETAILED DESCRIPTION

Example embodiments of the present invention are described in greater detail below with reference to the appended Figures. Before presenting the details of a method hereof and of a

cutting tool hereof, however, a few aspects, to which reference will be made later, shall be mentioned below.

When cutting a workpiece to be machined, the surface of the
5   workpiece is to obtain a desired three-dimensional geometry. This desired three-dimensional geometry on the surface of the workpiece is also referred to as a freeform surface.

The cutting of the workpiece to be machined occurs with the
10   aid of a cutting tool, a so-called cutter. For purposes of machining the workpiece, the cutting tool or cutter is moved relative to the workpiece. The movement of the cutting tool or cutter relative to the workpiece is described by so-called tool coordinates, the tool coordinates defining the position
15   of a tool reference point. The movement of the tool reference point in cutting the workpiece is referred to as the tool path or cutting path.

The cutting tool has a tool shank as well as a tool head
20   attached to the tool shank. When cutting, the tool head comes into contact with the workpiece to be machined. The properties of a cutting tool are determined by several geometric parameters that are generally specified in a tool coordinate system. This tool coordinate system originates in
25   the tool reference point, in which an axis or axis of symmetry of the tool shank intersects with one end or one tip of the tool head. Starting from this origin of the tool coordinate system, a first axis of the same extends in the direction of the axis of symmetry of the tool shank. The remaining axes of
30   the tool coordinate system each extend perpendicular with respect to the latter.

The parameters by which the properties of a cutting tool are defined in the tool coordinate system are, e.g., a diameter or
35   radius of the tool shank, a diameter or radius of the tool

head, a horizontal coordinate of a radius center point of the tool head as well as a vertical coordinate of the radius center point of the tool head, etc. Parameters such as angles between line segments and horizontal or vertical axes of the cutting tool are possibly included as well, the vertical axis extending in the direction of the tool axis and the horizontal axis extending perpendicularly with respect to this tool axis of the cutting tool.

The cutting of a workpiece for producing a defined three-dimensional freeform surface occurs by so-called five-axes cutting. In five-axes cutting, the cutting tool may be moved along five axes relative to the workpiece to be machined. Three axes are used for the linear movement of the cutting tool relative to the workpiece such that every point in space may be accessed. In addition to this linear movement along the so-called linear axes, the cutting tool may also be moved around a swivel axis as well as a tilting axis for undercutting. Rotational movements of the cutting tool are possible along the swivel axis as well as the tilting axis. This makes it possible to access all points in space without collision. The swivel axis as well as the tilting axis are also generally referred to as rotary axes.

Figure 1 illustrates a conventional cutting tool 10 that may be used in accordance with conventional systems for cutting freeform surfaces on workpieces.

Cutting tool 10 as illustrated in Figure 1 has a tool shank 11 as well as a tool head 12 attached to tool shank 11. Tool shank 11 has a diameter d_S and a radius r_S, where $r_S=d_S/2$. Tool head 12 has a radius r_K, radius r_K of tool head 12 corresponding to radius r_S of tool shank 11 in the case of the cutting tool illustrated in Figure 1. Accordingly, for cutting tool 10 illustrated in Figure 1, $rK=rS=dS/2$. Such a

cutting tool is also referred to as a spherical cutter. As
illustrated in Figure 1, tool head 12 does not protrude
laterally beyond an outer lateral surface of tool shank 11.

5   Figure 1 furthermore illustrates an axis 13 of tool shank 11.
Axis 13 of tool shank 11 intersects one end or one tip of tool
head 12 at a point 14, point 14 forming a point of origin for
a tool coordinate system.

10   Figure 2 illustrates a cutting tool 15 according to an example
embodiment of the present invention. Cutting tool 15 includes
a tool shank 16 and a tool head 17 attached to tool shank 16.
Furthermore, Figure 2 illustrates an axis or axis of symmetry
18 of tool shank 16 as well as a point 19, at which axis of
15   symmetry 18 of tool shank 16 intersects one end or one tip of
tool head 17.

A radius R_K of tool head 17 is greater than a radius R_S of tool
shank 16. Therefore: $R_K > R_S$. Also in cutting tool 15, tool
20   head 17 does not protrude laterally beyond an outer lateral
surface of tool shank 16.

As illustrated in Figure 2, radius R_K of tool head 17 is
greater than radius R_S of tool shank 16, e.g., greater than the
25   double radius R_S of tool shank 17 or its diameter D_S.
Therefore: $R_K >> R_S$.

Thus, Figure 2 illustrates that a radius center point 20 of
tool head 17 of cutting tool 15 does not lie in a region of
30   the tool shank, as in the case of spherical cutter 10
illustrated in Figure 1, but rather outside of the same. The
position of radius center point 20 is determined by a
horizontal coordinate E and a vertical coordinate F in the
tool coordinate system, a point of origin of this tool
35   coordinate system lying in point 19.

It should be noted that although radius R_K of tool tip 17 is greater than radius R_S of tool shank 16, it is however smaller than a smallest radius of curvature of the freeform surface to be cut. This may ensure that there is a low residual line formation and that the line spacing during cutting is thereby increased and the cutting time reduced. On the other hand, collision-free machining of the workpiece may be ensured.

Cutting tool 15 may be used for manufacturing rotationally symmetric, disk-shaped or ring-shaped components. These components may be rotor disks having integrated blading, i.e., so-called bladed disks, which are also referred to as blisks. These may be used in aircraft engines.

Furthermore, method for cutting freeform surfaces may be provided hereby. When cutting freeform surfaces, cutting tool 15 cuts a workpiece such that the desired freeform surface may be obtained. For this purpose, cutting tool 15 is moved along several defined cutting paths relative to the workpiece. Cutting tool 15 as illustrated in Figure 2 may be used.

First cutting paths as illustrated in Figure 1 may be produced in a first step with the aid of spherical cutter 10 if a CAM system used does not support special cutters. For spherical cutter 10 as illustrated in Figure 1, radius r_K of tool head 12 corresponds to radius r_S or half of diameter d_S of tool shank 11. Spherical cutters 10 are supported by a conventional CAM system. From these first cutting paths, second cutting paths are produced in a second step for the specific cutting tool to be used, whose radius R_K of tool head 17 is greater than radius R_S of its tool shank 16. The cutting tool to be used may be a cutter hereof.

Normal vectors of the workpiece surface to be cut are produced for ascertaining the second cutting paths for cutting tool 15 to be used from the first cutting paths that were produced by using spherical cutter 10. The first cutting paths include a

5 plurality of support points, a normal vector of the workpiece surface to be cut being produced for each support point of the first cutting paths. For producing the second cutting paths for the specific cutting tool 15 to be used, the support points of the first cutting paths are shifted relative to the

10 corresponding normal vectors, that is, in the direction of the normal vectors. For this purpose, the support points are shifted by the difference between radius r_K of tool head 11 of spherical cutter 10 and radius R_K of tool head 17 of the cutting tool 15 actually to be used. Expressed in other

15 words, the support points are shifted such that a point of contact of the cutting tool 15 to be used on a surface of the workpiece to be cut corresponds to the point of contact of spherical cutter 10 and is always in the region of the radius of the tool head of the cutting tool 15 to be used.

20

In this shifting of the support points, the coordinates that describe the position of the radius center point 20 of tool head 17 of cutting tool 15 are taken into account. As already mentioned above, this radius center point 20 of cutting tool

25 15 no longer lies on axis 18, but is rather defined by horizontal coordinate E and around vertical coordinate F. On the basis of these characteristic quantities and the corresponding characteristic quantities of spherical cutter 10, it is possible to perform the shift of the support points.

30

Consequently, according to the method, first cutting paths are produced, e.g., in a first step, with the aid of a spherical cutter, the radius r_K of the tool head corresponding to the radius r_S of the tool shank. These first cutting paths serve

35 as ancillary cutting paths. It is not a spherical cutter that

is to be used, but rather a cutting tool in which the radius R_K of the cutter head is greater than the radius R_S of the cutter shank, without however the tool head laterally protruding beyond an outer lateral surface of the tool shank. The

5   ancillary cutting paths are produced with the aid of a spherical cutter in which the radius r_S of the cutter shank corresponds to the radius R_S of the cutter shank of the tool actually to be used. The actual cutting paths for the cutting tool are produced from these ancillary cutting paths. This is

10   done by shifting the support points of the ancillary cutting paths in the direction of the normal vectors of the workpiece surface to be cut. The shift occurs by taking the radius r_S or the diameter d_S of the tool shank of the spherical cutter into account, these parameters corresponding to the radius R_S or the

15   diameter D_S of the tool shank of the cutting tool to be used. Furthermore, the shift of the support points occurs by using radius R_K of the tool head of the cutting tool and by using the radius center points of the tool heads of the spherical cutter and the cutting tool actually to be used. By a simple

20   subtraction of the corresponding geometric parameters, it is possible to determine the magnitude of the shift of the support points.

It is possible to use cutting tools in the cutting of complex

25   freeform surfaces on blisks, the tool heads of which have a greater radius than the tool shank of the cutting tool. This may allow for a greater line spacing to be set in the cutting process. The time required for cutting may be reduced. The effectiveness of the cutting process may be increased.